Sandia National Laboratories

Energy, Climate & Infrastructure Security

SSM SECURE SCALABLE MICROGRIDS It's the end of the grid as we know it

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Enabling Secure, Scalable Microgrids with High Penetration Renewables

Grand Challenge Laboratory Directed Research and Development

Vision

To develop tools that enable design and trade-off analyses of networked microgrids spanning the space from conventional to 100% stochastic generation.

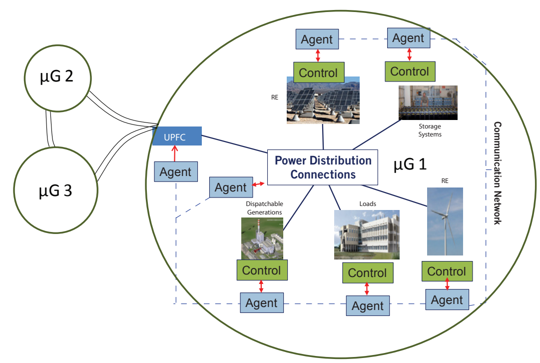
Energy Surety: A Matter of National Security

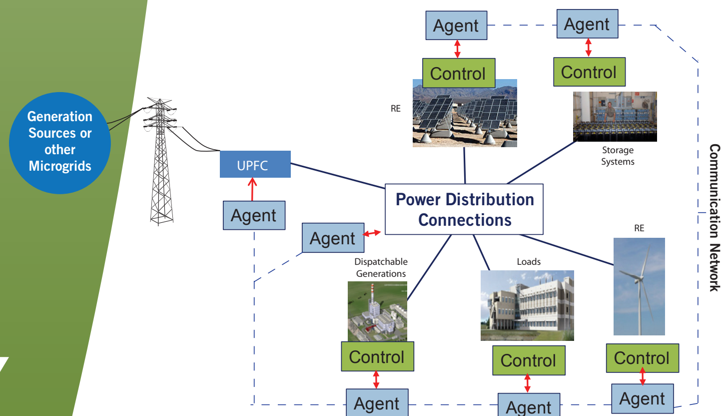
The present electric grid is based on a foundation created over 100 years ago. The infrastructure is topologically fixed, power sources are centralized and dispatchable (completely controllable), the loads are largely predictable, and the control of power flow at the load is essentially open-loop making it vulnerable to terrorist attacks, natural disasters, infrastructure failures, and other disruptive events. Further, this grid model limits renewables and other distributed energy sources from being economically and reliably integrated into the grid because it has been optimized over decades for large, centralized power generation sources.

Although issues of cost-effective and reliability have long been regarded as fundamental considerations of our present energy infrastructure, in recent years both the Department of Energy (DOE) and the Department of Defense (DoD) have turned attention towards energy surety—providing cost effective supplies of energy that are reliable, safe, secure, and sustainable. However, forward-looking energy surety requires the development of novel intelligent grid architecture in order to be robust, effective, and efficient.

SSM will enable:

- Unlimited use of renewable energy power sources
- Reduced fossil fuel-based power generation
- Reduced energy storage requirements
- Balanced control of generation, storage, and loads in an efficient and secure paradigm





Secure Scalable Microgrid (SSM)

The secure scalable microgrid (SSM) is a Sandia-developed grid architecture that divorces away from unidirectional power and limited information flow and, rather, adopts closed-loop controls and an agent-based architecture with integrated communication networks. Adding a feedback component to the input signal establishes an intelligent power flow control and provides a basis for the integration of renewables and distributed power sources into

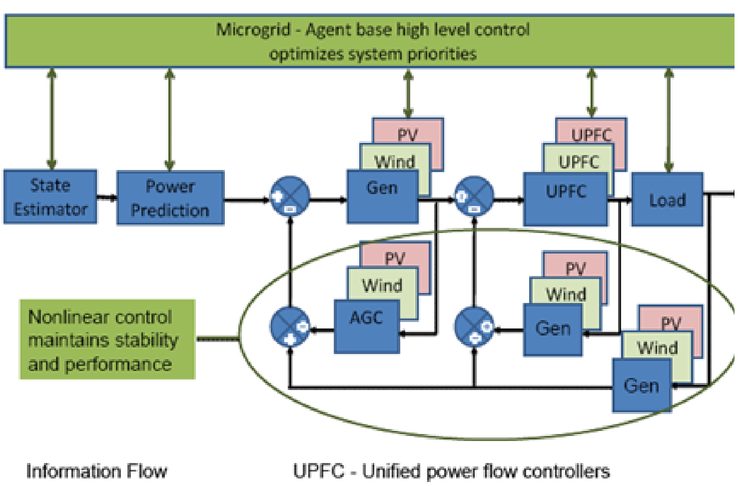
U.S. DEPARTMENT OF ENERGY

the electrical power grid. This bold approach will enable self-healing, self-adapting, self-organizing architecture and allow a trade-off between storage in the grid and information flow to control generation sources, power distribution, and loads.

Incorporating agent-based, distributed, nonlinear control to maintain reliable energy distribution while minimizing the need for excessive storage or backup generation will be a revolutionary step towards extreme penetration of renewable energy sources into the U.S. energy infrastructure. The development of dynamic nonlinear source models, scalable agent-based architectures and multi-time-variant simulations will be key components to this solution.

Closed-Loop Control

The SSM consists of a multilayer feedback control system. This new approach includes agent-based, closed loop architecture of the entire system with two main levels. The high-level layer, agent-based informatics architecture, regulates the mixture of energy resources, performs load leveling and prioritization and allows adaptive behavior. Basically, it chooses the network topology connecting the power generators, energy storage, and distribution/ transmission lines in order to service the loads within the SSM while optimizing the SSM priorities.



The low-level layer, distributed nonlinear control, ensures and maintains stability and transient performance of the network topology chosen by the high-level layer of the SSM. The interplay of these two levels is critical for the success of new control and informatics driven electric power grid. Specifically, the top-level layer must be effective and efficient in the selection process while the low level layer must guarantee stability and performance for non-linear systems.

Key Technical Objectives

Researchers will leverage capabilities and theories unique to Sandia, creating advanced models, nonlinear control theory, system control theory, and informatics and flexible experimental hardware testbeds as tools to enable the analysis and design of these complex systems. Ultimately, the goal is to advance and integrate new theories on distributed nonlinear control, agent-based closed-loop controls, informatics, and experimental microgrid hardware testbeds to enable adaptive microgrids and networked microgrids with guaranteed stability and transient performance.

By advancing these sciences and technologies, we are enabling reliable, resilient, secure, and cost-effective microgrids and interconnected microgrids making up the Smart Grid of the future.

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